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# NATIONAL VEGETABLE RESEARCH STATION

## NOTES ON THE STATION AND ITS WORK

WELLESBOURNE, WARWICK

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## NOTES ON THE STATION AND ITS WORK

The necessity for increasing food production in Britain during the 1939–45 war and the appreciation that this need would continue in future, led to the establishment of the National Vegetable Research Station at Wellesbourne, Warwickshire, and its Sub-Station at Paglesham, Essex, in September 1949.

The Station and its Sub-Station are controlled by a Governing Body which is incorporated as a company limited by guarantee, not having a share capital, and is registered as The British Society for the Promotion of Vegetable Research. The properties at Wellesbourne and Paglesham are leased to the Society by the Agricultural Research Council, and that Council provides the Society with funds for the development and running of the Station. The Governing Body is made up of nominees of the Lord President of the Council, the Minister of Agriculture, Fisheries and Food, the Secretary of State for Scotland, various universities, institutions and societies concerned with horticulture, vegetable producers (professional and amateur) and trade interests.

The soil and climate at Wellesbourne are similar to those of the nearby Vale of Evesham where vegetable production is an important industry. The soil is a sandy loam without excessive variation, and the land is flat. The area of 375 acres is large enough to permit long-term rotation between field experiments and to provide the isolation necessary for certain investigations; also to allow a farm unit to be run with the object of building up the soil fertility to the high level required for vegetable research. Wellesbourne is situated near the centre of England and is easily reached by rail and road.

The Sub-Station at Paglesham consists of 150 acres of fertile loam. The climate and other conditions in Essex account for its being the main vegetable seed producing area in England. The main purpose of this Sub-Station, therefore, is for the multiplication of stocks of seed of vegetables bred by the N.V.R.S. and for the investigation of problems related to seed production.

When the site for the Station was obtained in 1949 there were no buildings or services for research. Since then much building development has taken place and in 1959 the Station was honoured by having the main laboratory building officially opened by H.R.H. Prince Philip, Duke of Edinburgh. A team of about 50 scientists and a similar number of assistants has been built up and they deal with the breeding of improved varieties, the improvement and maintenance of soil fertility, the factors affecting crop growth, the study of irrigation, the control of pests, diseases and weeds, and the designing of experiments and analysis of the results.

The Station has close associations with the National Agricultural Advisory Service of the Ministry of Agriculture, Fisheries and Food, and is fortunate in being provided with facilities to test its findings at the N.A.A.S. Experimental Horticulture Stations in various parts of the country. In this way, results are being obtained which will be applicable to the different conditions in different regions thus assisting the Station to provide a service on a national scale to growers of vegetables, to other interests associated with this work, and to consumers of their products. Growers and others concerned with vegetable production may also join the N.V.R.S. Association and thus maintain close contact with the work of the Station.

The following is a brief synopsis of this work, fuller information on which can be obtained from the Station Annual Reports.

# PLANT BREEDING

The many excellent varieties of vegetables listed in seed catalogues have been produced largely by members of the Seed Trade, after careful and patient selection over many years. The programme of the Plant Breeding Section is therefore directed towards the production of improved varieties of vegetable crops in those cases where the breeding problems are apparently complex, and towards the fundamental side where new knowledge can lead to progress in the applied work, e.g. by evolving new breeding techniques.

The main breeding problems upon which work is in progress are listed below:

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| Asparagus | to produce a strain of seed which will give only male plants |
| Brussels sprouts | to improve uniformity, yield and quality by various methods, including the production of $F_1$ hybrids |
| Cabbage | to eliminate rosette-type heads from winter cabbage<br>to produce a dual-purpose spring cabbage variety suitable for either spring greens or hearted cabbage |
| Cauliflower | to produce a good quality, self-compatible autumn cauliflower |
| Celery | to combine the earliness of the self-blanching type with the quality of the green type |
| Lettuce | to produce a variety or varieties of summer cabbage lettuce resistant to downy mildew *(Bremia lactucae)* and mosaic virus disease |
| Onion | to develop uniform, high yielding, $F_1$ hybrids of good quality |
| Pea | to produce an early maturing, winter-hardy wrinkled-seeded variety |
| Tomato | to introduce resistance to *Didymella* stem-rot into outdoor commercial varieties |

Asparagus plants which are homozygous for the male character have been isolated so that it is now possible to produce an all male population. Such a population must, however, have high yield and good quality, and the ideal parents have not yet been found.

A Brussels sprout $F_1$ hybrid named Avoncross, is due for general release in spring 1967. The production of this variety demonstrates the effectiveness of the technique of inbreeding and subsequent combination of selected inbred types. The same inbreeding technique promises success in eliminating rosette-type heads from winter cabbage and also in producing a dual purpose spring cabbage variety. With the cauliflowers, on the other hand, the emphasis is on the isolation of self-compatible types in autumn cauliflower varieties. It is believed that such types can be produced without appreciable loss of vigour, and the self-compatibility will lessen seeding difficulties.

Two new lettuce varieties bred at the Station which are resistant to the common strain of downy mildew are due for general release in the near future. They are Avoncrisp, a Webb's Wonderful type, and Avondefiance, a butterhead type. Since they were bred, a new strain of the mildew fungus has been found to occur widely, and work is now on hand to introduce resistance to it. Progress has been made towards the development of a type that does not transmit mosaic virus through the seed. Resistance to lettuce mosaic has not yet been found in any *Lactuca* sp., but the search goes on.

$F_1$ hybrid onions have been produced, using male sterility in one parent as an aid to crossing, and the first variety appeared in N.I.A.B. trials in 1964. A canker-resistant parsnip, Avonresister, should be available for general release in 1966. It is smaller than the average commercial type, but gives a better yield when canker is prevalent. Winter hardiness has been transferred from the field pea into a range of wrinkled-seeded culinary types; lines now in N.I.A.B. trials should extend the processing season by about two weeks. A line of red beet which does not bolt when sown early to give a 'bunching' crop, has been produced and is now in N.I.A.B. trials; the incorporation of the single-seeded fruit character into the material is almost completed. The rate of progress of the project to introduce resistance to *Didymella* into outdoor tomato varieties has been hampered by the complicated inheritance of the resistance contributed by the wild parent *L. hirsutum*, and by the need to eliminate all its remaining characters. However, a *Didymella* resistant Harbinger is almost ready for trials and work is in hand on resistant forms of Moneymaker and Devon Surprise.

Seed production problems are also being studied, e.g., the optimum number of parent plants to be seeded together in order to maintain the standard of performance of an existing variety, and the effects of natural crossing and of stringency of selection on the variation within a variety. The techniques used at present in the maintenance of most outbreeding vegetable varieties are largely empirical and attempts are being made to put them on a scientific basis.

The Section is also responsible for maintaining supplies of nucleus stock seed of the Brussels sprout varieties Cambridge No. 1 and Cambridge Special which have already been marketed and were bred originally by the Horticultural Research Station formerly in existence in Cambridge. This work involves the production in isolation of small amounts of seed of the highest quality for multiplication by the National Institute of Agricultural Botany, the Seed Trade and others, and the carrying out of growing-on tests of such seed to ensure that quality is being maintained.

## CHEMISTRY

Long-term field experiments have been in progress since 1954 in which a succession of vegetable crops is being grown in plots which have received different types of cultivations and fertiliser treatments. The effects of these treatments on cropping are determined and the plots provide samples of plants and soil which are used in laboratory studies on the causes of the crop responses.

The most outstanding of these responses has been to the application of farmyard manure (FYM). Yields of all crops have been increased by its use and over the period of the experiments there has been a rapid deterioration in soil structure on the plots not receiving FYM.

It has often been suggested that frequent small doses of nitrogenous fertilisers are better than one dose before planting but the experiments have failed to support this suggestion. They have also indicated that the expensive hoof and horn meal has been less effective as a source of nitrogen than the equivalent amount of Nitrochalk.

Most vegetables have responded to applications of nitrogen and potash but phosphate has had little effect on yields. In 1960 the rates of fertiliser application were almost doubled but the resultant additional responses were small and the extra fertiliser has not compensated for lack of FYM. It has been found, however, that the annual application of FYM for five years has enabled a high level of crop production to be maintained for the next three years by fertiliser applications alone.

The basic reasons for the beneficial effects of FYM are being studied and evidence has been obtained that these arise at least in part from improvements in the soil structure and amounts of available soil moisture, and in the availability of nutrients, especially potassium.

Cultivation treatments have markedly affected crop growth and, with the exception of peas, all crops have grown best after continued deep ploughing and worst where the only primary cultivation has been rotary hoeing to a depth of 6-7 inches.

Over the years, several treatments have been shown individually to increase crop yields. An experiment is in progress to find out the effects of combining these treatments, and a combination of four different factors, spacing, irrigation, soil fertility and variety, is being studied.

The influence of micronutrients, such as iron, manganese, zinc and copper, on plant growth is being investigated. In certain circumstances the availability of these elements can be a limiting factor for crop yield. Iron plays a part in many processes associated with growth; the way in which the plant obtains iron from the soil and utilises it is being studied. The movement of micronutrients within plants is being compared with that of the major nutrients and radio-isotopes are being used in this work.

Studies are also in progress on soil aeration.

Oxygen is an important constituent of soil both within the air spaces and dissolved in the soil solution. The oxygen is used in respiration by plant roots and also by the micro-organisms present in soil. As these remove oxygen a gradient of oxygen concentration is established within the general bulk of soil and within each of the soil aggregates which make up this bulk. Under certain conditions the rate of removal of oxygen is

greater than its rate of diffusion into the centres of soil aggregates and zones are established with an oxygen content which is too low to support aerobic respiration of soil micro-organisms. In such zones, anaerobic decomposition of nitrogenous compounds and organic matter occurs, resulting in a loss of nutrients.

The conditions under which these circumstances arise are under investigation and these studies are enabling the minimal aeration conditions and size of soil aggregates for satisfactory microbial activity and plant growth to be defined. Studies are also in progress on the direct effect of aeration on the growth of plant roots.

## BIOCHEMISTRY

The biochemical unit is engaged on research on the role of potassium in plant nutrition, and on toxins produced by certain plant pathogenic fungi.

It has been shown by work in the Chemistry Section that the beneficial results from applications of FYM to vegetables may be related to the potassium status of the treated plants and that this element may play an important part in seedling nutrition. Further studies on this and related subjects are hampered by lack of basic information on the function of potassium in vegetables and the research is directed to the provision of such information.

The fungi which cause wilt diseases liberate toxins into the sap stream of infected plants. Work in the Plant Pathology Section has indicated new methods by which certain of the toxic effects may be tested and collaborative studies are in progress to attempt to isolate the active compounds. Such an investigation will assist in the understanding of the mode of action of the diseases.

## PLANT PHYSIOLOGY

The effects of environment (weather, manurial treatments, cultural factors and competition) on the growth, yield and quality of vegetables are being studied.

Before herbicides were available, widely spaced rows were necessary to enable the inter-rows to be cultivated mechanically—this being a cheap and effective means of weed control. Each year the number of herbicides and the skill in using them increases; thus it is anticipated that the use of mechanical inter-row cultivation for weed control will diminish and this will enable close row spacings to be used. Work has already shown that very close rows (3½in.) arranged in beds, can be used in commercial carrot growing. This gives a total yield up to 40 per cent greater than that given by normal row spacings (12 to 24 in.). It also enables the size of roots to be controlled more easily by variation of the plant density (plants per sq. ft.). Sowing date is another important factor affecting root size. In general, the earlier the sowing the higher is the yield, hence the larger are the individual carrots, and the higher the plant density the smaller are the individual carrots. Thus the production of crops in which the majority of roots are of a specific size at a given harvest date requires control of both sowing date and plant density. For instance, results obtained with the variety New Model indicated that if a high proportion of the total crop was required to be of canning size (¾ to 1¼ in. diameter) at harvest in mid-September, a plant density of 45 per sq. ft. should be used if sown in late April, whereas only 25 plants per sq. ft. should be used if the sowing were delayed until late May.

Investigations are also in progress on the combined effects of spacing, irrigation and soil fertility, and on the spacing of onions, red beet and potatoes. In this latter crop some success in the interpretation of density/yield data has been achieved by considering each eye on the set as equivalent to a seed.

The growth of carrots and red beet on one of the Chemistry Section's long-term manurial experiments has been studied for several years. The responses of the plants have been related to the treatments applied and the stages at which these treatments had the most influence have been ascertained. For example, the applications of FYM most markedly increased the growth rate of carrots during the first six weeks, whereas nitrogen sustained the growth of the leaves of red beet plants as they approached maturity The yearly variations in average yields and in the responses to the manurial treatments were mainly related to variations in the amount of rainfall.

Although seed crops of carrots and beet were formerly grown in Britain there has been an increasing tendency in recent years to grow only basic seed here from selected plants and to multip'y this in quantity in countries where the climate is more favourable for seed growing than that in England. It may, however, be generally advantageous for seed multiplication (especially of out-pollinated crops) to be carried out under the same conditions as those in which the crop is grown. For this and other reasons, therefore, an investigation has been started on methods of raising seed of these crops in Britain and of drying the seed artificially if necessary. Experiments on manurial treatments, spacings and steckling sizes for seed production are in progress at Wellesbourne and Paglesham. It has been found that certain manurial treatments applied to seed plants affect the phosphorus content of the seed produced and that the yield obtained from such seed can be correlated with its phosphorus content.

## IRRIGATION

Under ordinary weather conditions most crops react to additional water supply by increased production of foliage; this may or may not be accompanied by increased yield of marketable produce. Different kinds of crops respond differently to irrigation, and in some the response may vary according to the stage of growth of the crop at the time of irrigation.

The determination of these responses for vegetable crops is especially important in view of the usual summer shortage of water, just at the time when irrigation would seem most desirable. A considerable part of the effort of the Irrigation Section is devoted to finding ways of reducing the need for summer irrigation and of using comparatively small quantities of water in the most profitable manner.

Experiments at Wellesbourne and at the Experimental Horticulture Stations of the N.A.A.S. have demonstrated the desirability of sowing or planting in soil as near as practicable to field capacity; in spring-time sufficient irrigation water is usually available to achieve this. Reasonable, though not maximal, yields can then be expected in most years without additional summer irrigation. With crops which show marked response to drought or to added water at well-defined stages of growth, it is obviously best to irrigate only when this will result in increased marketable yield, and to withhold water at other stages of growth.

Short periods of rainless weather often occur in summer, and experiments are being carried out to determine the effects on yield of droughts of two or three weeks duration, at different times during the life of the crop. It has been found that, with crops sown or planted in soil near to field capacity, the nearer to harvest the drought occurred, the greater was its depressing effect on yield. This result was obtained with cauliflower, lettuce, cabbage, pea, broad bean and radish.

Investigations are in progress into the use of mulches and of wider plant spacing than usual, again with the object of reducing the need for irrigating field crops in summer.

It seems likely that water shortage will frequently preclude the grower from re-wetting the soil to the full depth of rooting of the crop, and the possible effects of this on water and nutrient uptake are being studied.

The water-holding capacities and moisture release characteristics of a range of typical vegetable soils are being determined, using pressure-membrane and suction-plate techniques. Such information is needed when applying experimental results obtained on one soil to other soils of differing type, and also may eventually be useful in helping to decide on the allocation of irrigation water supplies in different districts.

Changes in soil water-holding capacity resulting from cultivation and from the addition of FYM have been demonstrated and the effects of soil capping and short-term soil temperature changes such as may result from irrigation have been investigated.

In most of the experimental work mentioned above, the soil moisture status is estimated by means of an extension of the Penman meteorological method, and checked by gravimetric determinations of the moisture content of soil samples. The influence of weather factors on water use by crops and evaporation from the soil is measured by means of evaporimeters and lysimeters especially developed for the purpose, and a simple soil moisture deficit indicator suitable for use by growers has been devised.

It is becoming increasingly important to maintain continuity of production of certain crops to ensure an even supply of produce to markets. In order to achieve this with the cauliflower crop, studies have been started to determine the environmental factors influencing the growth and development of the cauliflower plant and the best cultural methods to obtain an even supply of good quality heads from July to November.

## ENTOMOLOGY

Research is being carried out on a number of insects of economic importance to vegetable crops. It includes biological studies, the development of control methods, investigations into the persistence of insecticides and the effect of these materials on beneficial insects and on crop flavours.

With the development of strains of the cabbage root fly resistant to aldrin, dieldrin and B.H.C., alternative insecticides are being sought that will control such strains. Factors governing the development and spread of insecticide resistant root flies from a point of origin into neighbouring brassica crops are also being studied. Predatory beetles and parasites of the cabbage root fly eggs and larvae have been shown to be important natural enemies of this pest. In the presence of small amounts of aldrin and dieldrin as residues in soil, the numbers of predators can be severely reduced with a consequent increase in the numbers of the pest and the damage it may cause. Taste and smell appear to be the most important factors by which the cabbage root fly recognises brassica plants, before it lays its eggs on or around them. These plants are characterised by certain mustard-oils and glucosides which themselves will stimulate flies to lay. The quality of early Brussels sprout crops grown for quick-freezing can be lowered by the presence of cabbage root fly larvae in the sprouts at harvest.

Since aldrin or dieldrin when applied to the soil leave residues which are very persistent and may be harmful, alternative insecticides are being sought with a persistence that corresponds more closely with the period of biological usefulness. Diazinon and disulfoton have been found to be effective substitutes for aldrin or dieldrin in the control of the carrot fly and they do not persist in the soil for long periods.

Carrot-willow aphid can be readily controlled with foliar sprays of demeton-methyl, but this aphid is a vector of carrot motley dwarf virus disease, and to control both aphid and virus presents a much more difficult problem. The biology of the aphid is being studied from the viewpoint of virus transmission and an attempt is being made to assess the relative importance to the carrot crop of the damage caused by the aphid and by the virus which it carries. Although carrot varieties thought to be aphid resistant have been tested, all have been found to be equally susceptible to attack. When mixed with the soil, granules containing disulfoton or phorate give a high control of this pest as well as of carrot fly.

A strain of the peach-potato aphid which is resistant to organophosphorus insecticides has developed in the glasshouses at Wellesbourne. Investigations to date show that the condition is not permanent and when reared away from these insecticides the strain eventually loses its resistance to them.

The persistence and behaviour of insecticides in soil is being studied. Precise and highly sensitive methods of chemical analysis using paper, thin-layer and gas chromatography, have been developed to measure the decline of residues of organo-chlorine insecticides such as aldrin, dieldrin, lindane and DDT in soil. A series of microplots is used for the more exact work on the behaviour and performance of insecticides in soil and their uptake into crops such as carrots.

## PLANT PATHOLOGY

Vegetable diseases are caused by fungi, bacteria or viruses and the primary function of the Plant Pathology Section is to find the best means of control of these diseases.

Before this can be attempted the cause of the disease must be established and the infection cycle studied. From such an investigation the mode of transmission of the pathogen is obtained and, possibly, the conditions conducive to such transmission. It may then be possible to attack the pathogen directly with chemicals at the point in the infection cycle where it is most vulnerable, or alternatively to modify the conditions

of growth of the host plant so that they are unfavourable for the development of the pathogen. In addition to such measures, it is often desirable to develop resistant varieties. Such work is normally undertaken jointly by the Plant Pathology and Plant Breeding Sections.

Direct control methods have already been developed for two diseases, both of which have become of importance since 1945. Watercress crook root, caused by a water fungus, has been controlled by the addition of minute traces of zinc to the water feeding the beds. This kills the swimming spores of the fungus. The control of silvering of beet has been achieved by killing the causal bacteria in the seed by treatment with streptomycin.

Studies on lettuce downy mildew are concerned mainly with the existence of different strains of the fungus which causes the disease. Other downy mildew diseases being investigated are those of peas and brassicas.

Several vegetable pathogens are seed-borne and a number of these are under investigation, including *Mycosphaerella* and *Ascochyta* on peas, *Alternaria* on brassicas and carrots, *Stemphylium* on carrots, and *Septoria* on celery. New methods of eliminating the fungi from the seeds are being studied.

Other pathogens are soil-borne. These include at least three fungi causing parsnip canker, against which control can be obtained by modification of the cultural conditions to produce smaller roots. A canker-resistant parsnip variety has been bred. Another group of soil-borne fungi, species of *Fusarium* and *Verticillium*, invade plants through their roots and then grow in the sap stream causing serious wilt diseases of peas, beans, tomatoes and other plants. Resistant varieties are being developed and work is also in progress on the mechanism of invasion of plants by the fungi.

Virus diseases are prevalent in vegetables and cannot be cured by chemical treatment. Attempts must therefore be made to remove the source of infection and to reduce the spread of disease by attacking the "vector"–usually an insect but sometimes a soil eelworm or fungus. Lettuce mosaic is seed-borne and the use of virus-free seed has been shown to reduce disease in the subsequent crop very considerably. Carrot motley dwarf is carried by aphids and studies are in progress on these (in collaboration with the Entomology Section) and on resistant carrot varieties. Lettuce big vein virus has been shown to be transmitted by the soil fungus *Olpidium* and it has recently been found that rhubarb can contain many viruses, some of which may be carried by eelworms.

Such studies require a knowledge of the casual viruses and these are being purified. They are then used for the preparation of antisera as an aid to rapid identification of the diseases.

## WEED INVESTIGATIONS

This Section is engaged in studies of both cultural and chemical methods of weed control and in the investigation of relevant aspects of the ecology of weed species.

The weeds which are important in vegetable production are mainly annuals which reproduce by seed, and a survey has shown that it is not unusual for land carrying commercial crops to contain more than 100 million weed seeds per acre, all of which are capable of germinating. Estimates made at the start of long-term experiments in 1953 showed one field at Wellesbourne to have 230 million per acre in the top 6 in. of soil. It was found that under clean cropping the population was reduced by approximately half in each year, so that after four years of vegetable cropping the number of seeds was less than 10 per cent of that originally present. It was also found, however, that if weed control was not complete, in a wet season for example, then a sharp increase in the seed population could occur. The effects of different manurial and cultivation treatments on the numbers of weed seeds have been studied, and work is in progress on the factors concerned in germination and dormancy of seeds of important weed species.

The evaluation of chemicals as potential herbicides for use in vegetable crops forms a major part of the Section's work. Each year, field experiments are conducted in which the effects of promising chemicals on crops and weeds are determined, and the results, in conjunction with those of workers elsewhere, provide a basis from which practical recommendations can be developed. In collaboration with the Physiology

Section, herbicides are examined in experiments with different crop densities and patterns of arrangement. Other lines of study include the persistence in the soil of residual soil-acting herbicides and the development of bioassay methods for the determination of small amounts of these materials in soil. A study of the adverse effects on vegetable crops of low doses of growth-regulator herbicides, such as might occur in spray drift from cereal crops, etc., has recently been completed.

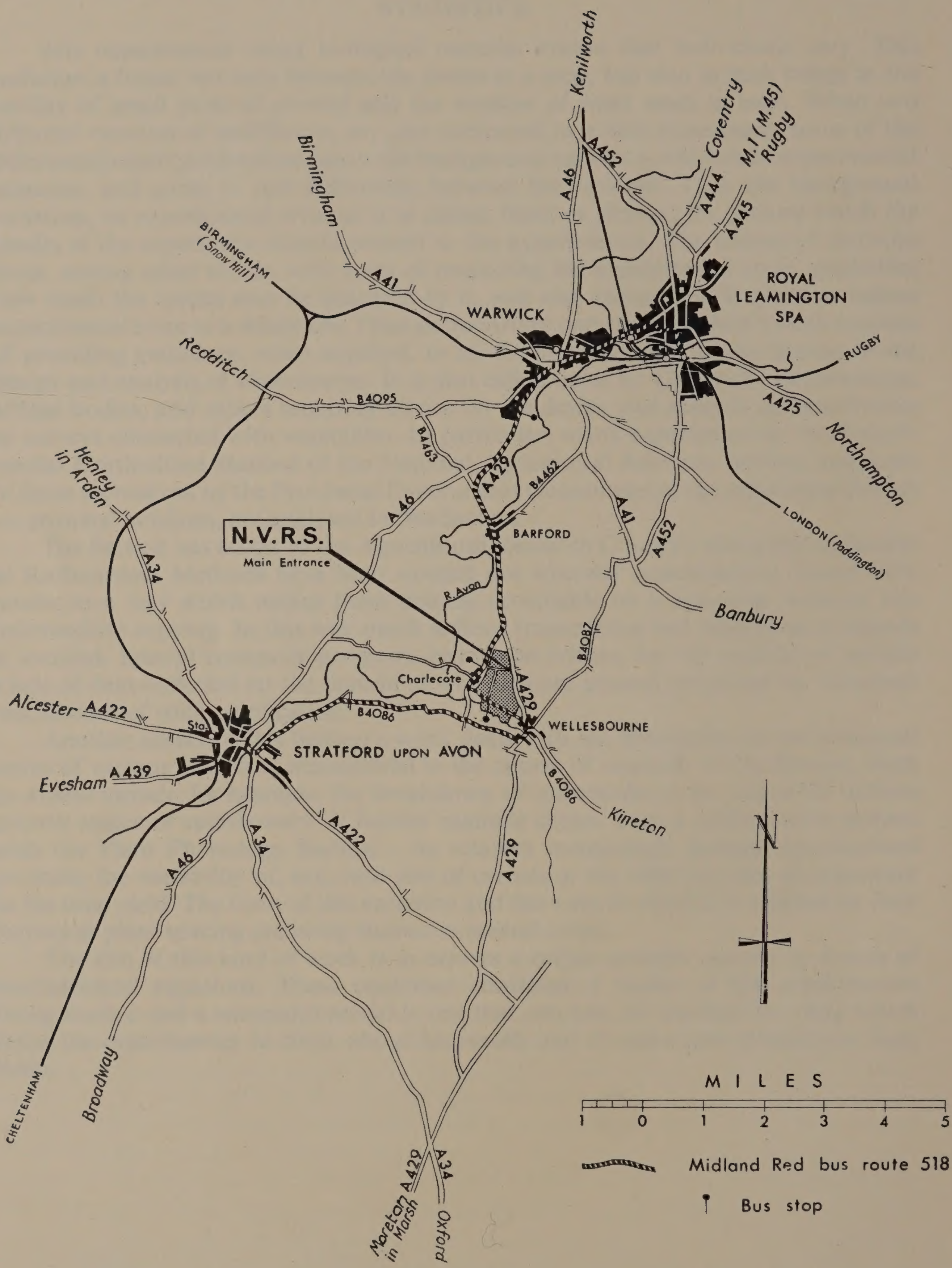
## STATISTICS

Any experimenter using biological material knows that individuals vary. This variation is found not only between the plants in a crop, but also in such things as the fertility of small plots of ground and the number of weed seeds in each. When two different varieties of cauliflower, say, are compared in a field experiment, some of the difference in their yield will be due to this background variation, which is an experimental nuisance, and some to real differences between the varieties. Thus the background variation, or *experimental error* as it is called, blurs or distorts the picture which the results of the experiment should present to the experimenter. The science of statistics deals, among other things, with ways of measuring the experimental error, predicting how much the results may be distorted by it, and with techniques designed to reduce experimental error to a minimum. Thus an important part of the Section's work consists of providing assistance, when required, to all the other Sections of the Station in the design and analysis of experiments. It is also called upon by University Departments, official bodies, and others requiring advice on the design and analysis of experiments or surveys connected with vegetables. In particular, many experiments at the Experimental Horticulture Stations of the National Agricultural Advisory Service, and some of those carried out by the Provincial Experiments Committees of the same organisation on growers' holdings, are analysed in this Section.

The Section has access to the Agricultural Research Council's electronic computer at Rothamsted. Methods have been worked out whereby experimenters record their results in a way which makes them directly acceptable by a computer without any intermediate copying. In this way much tedious transcribing and tabulation of figures is avoided. Special computer programs have been written for the analysis of certain kinds of data collected on the Station as well as more general programs for statistical calculations of wider application.

Another aspect of this Section's work deals with the description in mathematical terms of various processes encountered in the course of research on the Station. Such processes include, for example, the breakdown of insecticides in the soil or the various growth stages of cauliflowers. A further example comes from a collaborative project with the Plant Physiology Section. As retailers increasingly demand standardised produce, the variability of, say, root size of carrots in the field becomes as important as the total yield. The form of this variation and the ways in which it is affected by such factors as plant spacing are being studied in several crops.

The aim of this kind of work is to express a rather complex pattern by means of mathematical equations. These equations constitute a model of the phenomenon being studied and a successful model is one that can sum up the data in a way which helps the experimenter to think about his results and to make new predictions from them.

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